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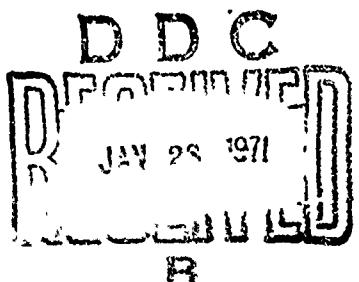
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**CRACKS, A FORTRAN IV DIGITAL COMPUTER
PROGRAM FOR CRACK PROPAGATION ANALYSIS**

ROBERT M. ENGLE, JR.

TECHNICAL REPORT AFFDL-TR-70-107

OCTOBER 1970



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FOREWORD

This report was prepared by Robert M. Engle, Jr. of the Solid Mechanics Branch, Structures Division, Air Force Flight Dynamics Laboratory. The work was conducted in-house under Project 1467, "Structural Analysis Methods," Task 146704, "Structural Fatigue Analysis," with Mr. Robert M. Bader as Project Engineer.

This report covers research conducted from July 1969 through February 1970.

This technical report has been reviewed and is approved.



F. J. JANIK, JR.
Chief, Solid Mechanics Branch
Structures Division
Air Force Flight Dynamics Laboratory

ABSTRACT

This report presents a detailed description of a computer program for analyzing crack propagation in cyclic loaded structures. The program has the option of using relationships derived by Forman or by Paris for crack growth. Provisions are made for both surface flaws and "through cracks" as well as the transition from the former to the latter. The program utilizes a block loading concept wherein the load is applied for a given number of cycles rather than applied from one cycle number to another cycle number. Additional features of the program are: variable print interval, variable integration interval, and optional formats for loads input. Detailed input instructions and an illustrative problem are presented.

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SYMBOLS

Mathematical Symbol	FORTRAN Symbol	Physical Definition
a	A	Half crack length
a_0	AZERO	Initial half crack length
b	B(2)	Plate half-width
c	C	Material constant
c	SMALLC	Surface flaw half-width
da/dN	DADN	Crack propagation rate
K_c	KSUBC	Critical stress intensity factor
ℓ_c	B(3)	Characteristic length
N	N	Cycle
n	SMALLN	Material constant
R	R	Stress ratio ($\sigma_{\max}/\sigma_{\min}$)
t	THICK	Material thickness
β_i	BETA(I)	Individual correction factor
β_T	BETAT	Total combined correction factor
ΔK	DELTAK	Stress intensity factor range
$\Delta \sigma$	TSUBA	Applied tensile stress range ($\sigma_{\max} - \sigma_{\min}$)
σ	SIGMA	Applied tensile stress
σ_{ys}	SIGMAY	Material yield stress

SECTION I
INTRODUCTION

The total service life of a structure is often dependent upon the total amount of crack growth which can be tolerated prior to the formation of the critical size flaw or crack. An analysis which can predict this growth, under variable amplitude loading, leading to the critical crack length is a valuable aid in establishing safe operating periods and inspection intervals.

An automated procedure is presented in this report which will permit the user to examine the crack propagation of various flaw shapes including surface flaws. Provision is also made for transition from a surface flaw to a "through crack." The computer program, CRACKS, is written entirely in FORTRAN IV for the IBM 7044/7094 Direct Coupled System (DCS). A source listing is given in Appendix I.

SECTION II
MATHEMATICAL FORMULATION

1. CRACK PROPAGATION RATE

In the early 1960's, P. C. Paris (Reference 1) determined that the rate of crack propagation under cyclic loading is primarily related to the stress-intensity-factor range, ΔK . Paris proposed an exponential relationship of the following form:

$$\frac{da}{dN} = c_p (\Delta K)^{n_p} \quad (1)$$

In 1967, Forman, Kearney, and Engle published a paper (Reference 2), in which Paris' equation was modified to take into account the effects of load ratio, R , and crack growth instability as ΔK approaches K_c . These modifications led to a relationship of the following form:

$$\frac{da}{dN} = \frac{c_f (\Delta K)^{n_f}}{(1-R) K_c - \Delta K} \quad (2)$$

Both of these relationships have proved useful in crack-propagation analysis and hence provision is made in CRACKS for both.

2. STRESS INTENSITY FACTOR

The basic unit of fracture mechanics is the stress intensity factor, K . For crack propagation analysis, the applied crack tip stress intensity factor, K , must be less than the material's toughness (K_c) or fracture occurs. This applied crack tip stress intensity factor, K , is a function of geometry and type of loading. For a central crack in an infinite width plate, the stress intensity factor may be written as follows:

$$K = \sigma \sqrt{\pi a} \quad (3)$$

This equation will take different forms based upon the geometry and the loading. For many cases, however, these effects may be treated as modifiers or correction factors to Equation 3. Thus, a more general form would be:

$$K = \sigma \sqrt{\pi a} \beta_T \quad (4)$$

These correction factors will be described in more detail in the following section.

Some investigators (Reference 3) have modified Equation 4 by removing the factor π from under the radical giving:

$$\kappa = \sigma \sqrt{\sigma} \beta_T \quad (5)$$

Equation 4 and Equation 5 are both prevalent in the literature and are included in the computer program.

The stress-intensity-factor range, ΔK , is defined as:

$$\Delta K = K_{\max} - K_{\min}$$

Substituting Equation 4 into this relation gives:

$$\Delta K = \Delta \sigma \sqrt{\pi \sigma} \beta_T \quad (6)$$

Similarly, substituting Equation 5 will yield:

$$\Delta K = \Delta \sigma \sqrt{\sigma} \beta_T \quad (7)$$

3. CORRECTION FACTORS

Equations 6 and 7 represent stress-intensity-factor ranges for a centrally cracked infinite panel if β_T is unity. For other geometries, β_T must be modified. For various combinations of geometries, β_T will become combinations of different β_i which will account for these separate effects. For example, in the program, β_2 corrects for finite width and β_3 can correct for a crack emanating from a circular hole. Hence, for a crack emanating from a hole in a finite width panel, β_T would be the product of β_2 and β_3 . The program provides for up to ten β_i of which only four are active at the present time. Thus, in general,

$$\beta_T = \prod \beta_i \quad (i = 1, 10) \quad (8)$$

The four active correction factors in the program at the present time are explained below:

β_1 - CONSTANT MULTIPLIER

This provides the analyst with the capability to scale loads or modify ΔK by a constant factor

β_2 - FINITE WIDTH TANGENT FUNCTION

This corrects for a finite width plate. The form of this correction is (Reference 4)

$$\beta_2 = \sqrt{\frac{2b}{\pi a} \tan \left(\frac{\pi a}{2b} \right)} \quad (9)$$

where "a" and "b" are as shown in Figure 1.

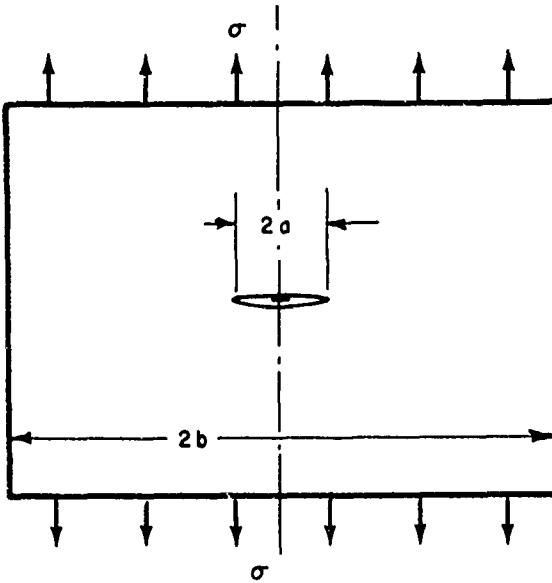


Figure 1. Griffith Crack in a Finite Width Plate

β_3 - TABULAR CORRECTION FACTOR

This permits the analyst to apply correction factors which appear in the literature as discrete data. The form of this correction is

$$\beta_3 = f(a/\ell_c) \quad (10)$$

An example is the crack emanating from a circular hole (Reference 4). In this case, "a" and " ℓ_c " are as shown in Figure 2.

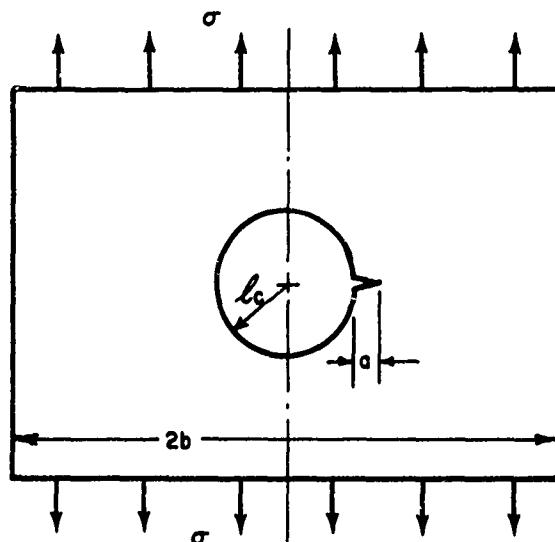


Figure 2. Crack Emanating from a Circular Hole

β_4 - ELLIPTICAL SURFACE FLAW CORRECTION

The expression for the stress intensity factor developed by Irwin (Reference 5) is given as

$$K = \frac{1.1 \sigma \sqrt{\pi a}}{\left[\Phi^2 - 0.212 (\sigma / \sigma_{ys})^2 \right]^{1/2}} \quad (II)$$

where

$$\Phi = \int_0^{\pi/2} \left[1 - \left(\frac{c^2 - a^2}{c^2} \right) \sin^2 \theta \right]^{1/2} d\theta$$

The geometry of the surface flaw is defined in Figure 3.

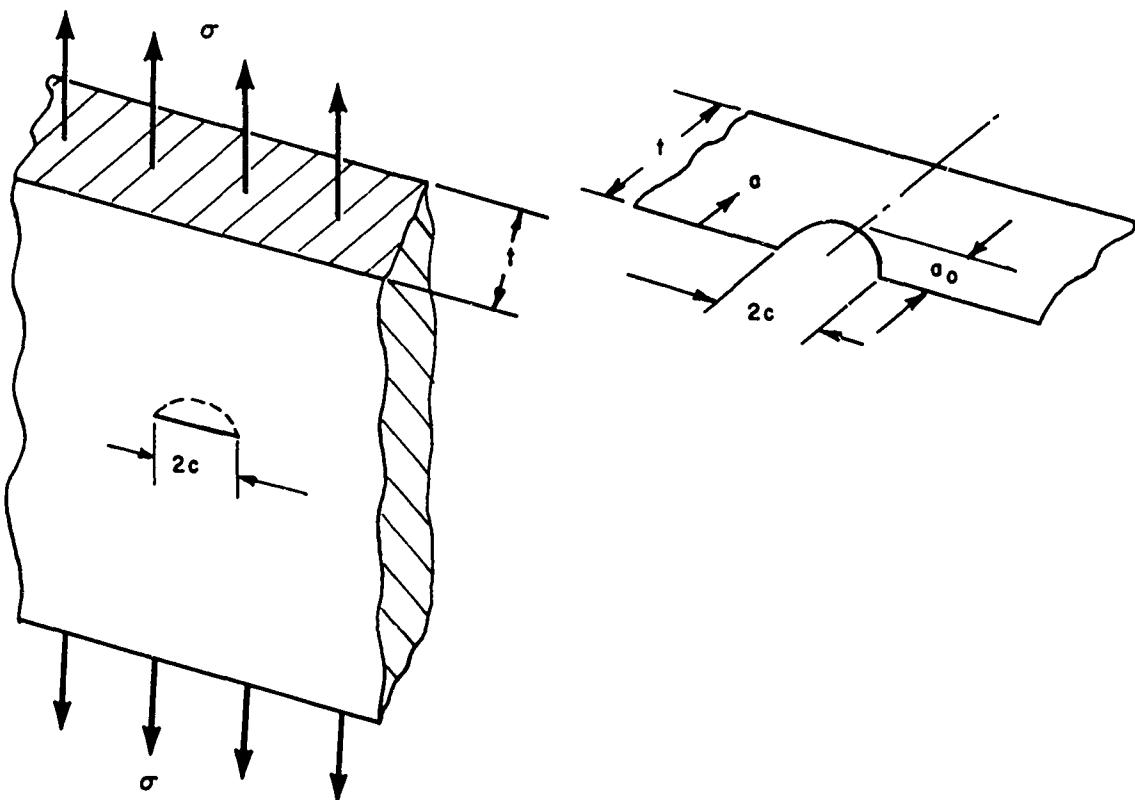


Figure 3. Surface Flaw Geometry

As the surface flaw approaches the back surface of the material, a magnification of the stress intensity factor takes place. This is accounted for by a magnification factor, M_k , which is a function of both a/t and $a/2c$. The magnification factor used in CRACKS has been obtained from Reference 6 and is included in Figure 4 for various flaw shapes ($a/2c$ values). Although this data has been derived for aluminum, it is in close agreement with the results of Kobayashi (Reference 7) and Smith (Reference 8) for general applications. Hence, Equation 11 may be written as

$$K = 1.1 M_k \sigma \sqrt{\pi a / Q} \quad (12)$$

where

$$Q = \Phi^2 - 0.212 \left(\frac{\sigma}{\sigma_{ys}} \right)^2 \quad (13)$$

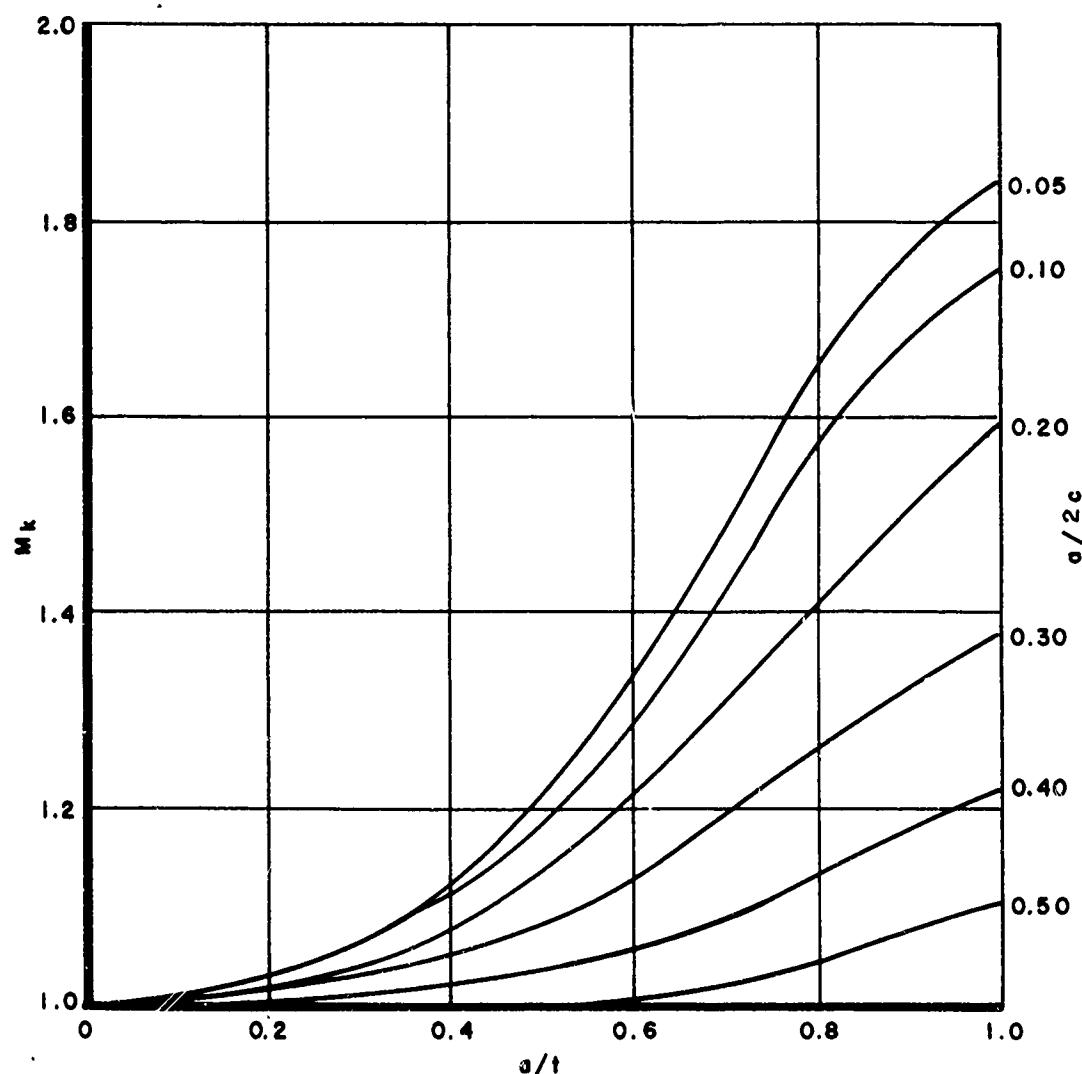


Figure 4. Magnification Factor Curves

Since Q is a function of σ , it is not convenient to develop an equation of the form of Equation 6. It is instead more convenient to obtain K_{\max} and K_{\min} and thus obtain ΔK . So, from Equations 12 and 13 we obtain

$$K_{\max} = 1.1 M_k \sigma_{\max} \sqrt{\pi a / Q_{\max}} \quad (14a)$$

$$K_{\min} = 1.1 M_k \sigma_{\min} \sqrt{\pi a / Q_{\min}} \quad (14b)$$

From these equations we see that the obvious expression for β_4 is

$$\beta_4 = 1.1 M_k \quad (15)$$

and we can then write

$$\Delta K = \sqrt{\pi a} \left[\frac{Q_{\max}}{\sqrt{Q_{\max}}} - \frac{Q_{\min}}{\sqrt{Q_{\min}}} \right] \beta_4 \quad (16)$$

The translation from a surface flaw to a through crack is chosen to be the point when the plastic zone reaches the back face of the material. The value of "a" for which this occurs is given as

$$a_t = t - \frac{1}{2\pi} \left(\frac{K_{\max}}{\sigma_{ys}} \right)^2 \quad (17)$$

where K_{\max} is defined by Equation 14a. At this point an effective through-crack length is calculated and the program then continues, now using Equation 6 for ΔK , with β_4 set to unity.

SECTION III

COMPUTER PROGRAM FOR CRACK PROPAGATION ANALYSIS (CRACKS)

The program described below was written in FORTRAN IV for the IBM 7044-7094II Direct Coupled System. The program consists of seven subprograms, each of which has a specific task to perform. These subprograms and their functions are:

CRACKS - reads in data, sets up calculations, and prints the results.

F - evaluates crack propagation rate, da/dN.

RK1DES - variable-step Runge-Kutta integration routine which integrates da/dN over each load block.

TBLKUP - linear interpolation scheme for use with β_3 .

ELIP2 - routine to evaluate the complete elliptic integral of the second kind to calculate Φ for use in Equation 12.

TIFANY - block data subroutine containing data for Tiffany's M_k curves as a function of a/t and a_{2c} .

TRP2 - parabolic interpolation routine for a function of two variables which is used to determine M_k for Equation 13.

A simplified flow chart depicting the transfer of information from the subprograms discussed above is given in Figure 5.

1. DESCRIPTION

The CRACKS computer program integrates the crack-propagation-rate equation to obtain crack growth versus cycles. The program provides options for the two prevalent forms of this equation (Equations 1 and 2). Many crack geometries may be modeled using the correction factors discussed in Section II, paragraph 3. A transition from a surface flaw to a through crack is provided (Equation 17). As a convenience, the program makes provisions for two forms of spectrum input, maximum and minimum stresses, or stress range and load ratio. The program also has the capability to run multiple problems merely by loading data decks in sequence.

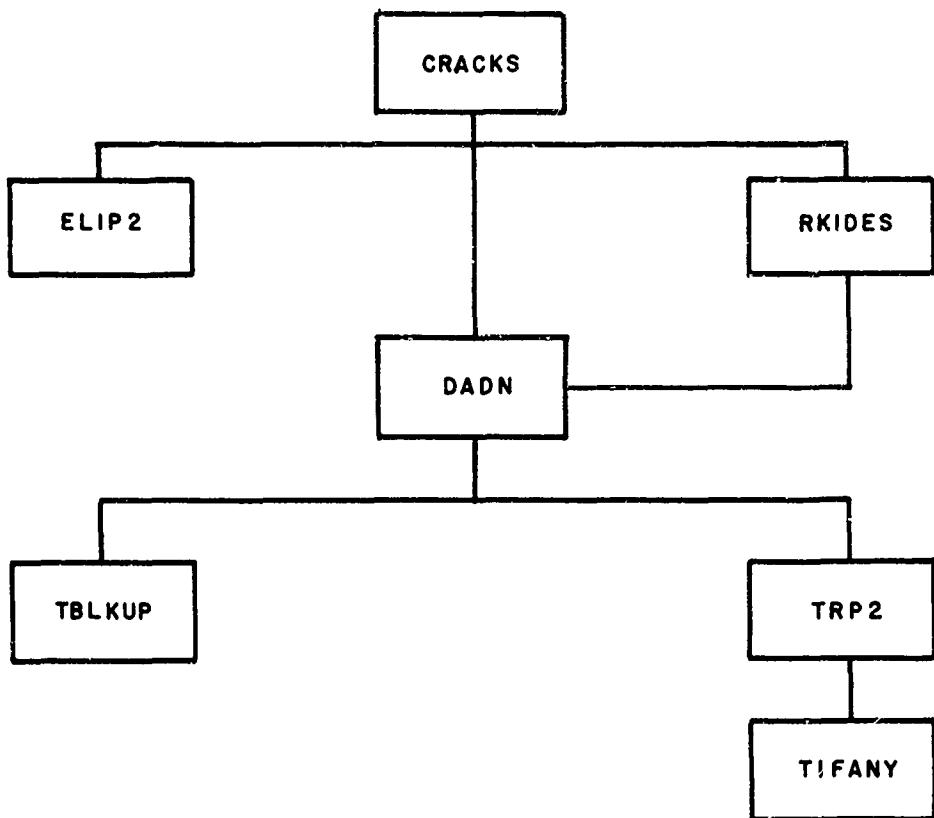


Figure 5. Information Transfer Flow Chart

2. INPUT INSTRUCTIONS

The input to the program consists of four basic sections: analysis selection, material properties, geometry definition, and loading. In addition, there are controls on print interval, repetition of load spectrum, and descriptive data. Detailed instructions on inputting the data cards are given below in the following manner:

- a. Card number and contents
- b. FORTRAN name for each variable
- c. Format of card
- d. Description of each variable

Card 1 Descriptive Information

TITLE

FORMAT (14A6)

TITLE - any information to define the problem for the user.

Card 2 Analysis Selection, Material Description

EQN, MATID

FORMAT (A6, 4X, 7A6)

EQN - alphabetic indicator governing choice of analysis.

The choices are: FORMAN - use Equations 2 and 6

PARIS - use Equations 1 and 6

NASAF - use Equations 2 and 7

NASAP - use Equations 1 and 7

MATID - alphanumeric identification to label material (may be left blank)

Card 3 Material Properties

C, SMALLN, KSUBC, SIGMAY

FORMAT (4E10.0)

C - material constant in Equations 1 and 2

SMALLN - exponent in Equations 1 and 2

KSUBC - fracture toughness of material

SIGMAY - yield stress of material, need only be input when running a surface flaw analysis.

Card 4 Initial and Allowable Crack Lengths

AZERO, AMAX

FORMAT (2E10. 0)

AZERO - initial half crack length

AMAX - allowable half crack length. If zero, program assumes infinite allowable length.

Card 5 Correction Factor Information

BETAL, I, BI, BII

FORMAT (A4, I1, 5X, 2E10. 0)

BETAL - label for correction factors. Alphabetic characters, "BETA"

I - indicator for correction factor selection. For permissible values see Table I

BI - variable for correction factor (see Table I)

BII - secondary variable for correction factor, (see Table I)

If I equals three, a table of points for the correction factor follows the BETA3 card immediately. The format of this card is as follows:

AOVERB, BETATB

FORMAT (2E10. 0)

AOVERB - ratio of crack length to characteristic length

BETATB - tabular value of β_3 corresponding to this ratio

Again, note that the BETAO card input must always be present and must be the last BETA card if others are present.

Card 6 Initial Cycle, Number of Applications

NZERO, NFLITE

FORMAT (E10. 0, I10)

NZERO - number of the initial cycle for this computer run.

NZERO is the cycle corresponding to AZERO.

NFLITE - this defines the number of times the input load spectrum will be applied.

TABLE I
CORRECTION FACTORS

I	Correction Factor	B I	B II
1	Constant (β_1)	Constant value	—
2	Finite Width (β_2)	Plate half width	—
3	Tabular (β_3)	Characteristic length	Number of points in table
4	Surface flaw (β_4)	Flaw half width	Material thickness
5 - 9	Inoperative at present	—	—
0	End of corrections (Must always be present)	—	—

Card 7 Load Format Selector

LOADS

FORMAT (A5)

LOADS - alphabetic indicator governing choice of input load format.

"SIGMA" - input σ_{\max} and σ_{\min} "RANGE" - input $\Delta\sigma$ and RCard 8 Loads and Print Controls

LABEL, $\left\langle \begin{array}{c} \text{SIGMAX} \\ \text{or} \\ \text{DELTAT} \end{array} \right\rangle$, $\left\langle \begin{array}{c} \text{SIGMIN} \\ \text{or} \\ \text{R} \end{array} \right\rangle$, CYCLES, NINT, NPRINT

FORMAT - (A5, 5E10.0)

LABEL - any five characters to identify load block. May be left blank. After the last load card, a card with "END" in LABEL is required.

SIGMAX - maximum applied tensile stress

DELTAT - applied tensile stress range

SIGMIN - minimum applied tensile stress

R - stress ratio

CYCLES - number of cycles in this load block

NINT - integration interval for this load block. If NINT is zero,
the program sets NINT equal to CYCLES.

NPRINT - print interval for this load block. If NPRINT is zero,
the program sets NPRINT equal to NINT.

3. RESTRICTIONS

Certain restrictions and limitations must be recognized or the capacity of the program will be exceeded. In general, violation of these restrictions will not result in termination of the computer run. Hence, stacked problems may be salvaged even though an error occurs in one of the first few data decks.

a. Program Capacity

The program will not accept more than 1000 load cards or 100 cards for the tabular correction factor. This is an arbitrary choice of numbers and may be changed by modifying the appropriate DIMENSION statements within the source deck.

b. Print Interval

Because of the variable step nature of the Runge-Kutta integration scheme, it is inconvenient to generate printout at intervals less than the integration interval. Hence, NPRINT is always greater than or equal to NINT.

c. Negative Loads

The theory developed in References 1 and 2 does not permit negative loading. This leads to the requirement that σ_{\max} , $\Delta\sigma$, and R must always be greater than or equal to zero.

4. OUTPUT

The output generated by CRACKS is, for the most part, self-explanatory. The first page of output consists of a display of the input data which define the problem. The next section of output consists of a printout of the input load spectrum. If the spectrum is input in terms of maximum and minimum stresses, these are then changed within the program to stress ranges and stress ratio and these are also printed out.

After the problem has been completely specified, the program begins calculating the increase in crack length by integrating either Equation 1 or Equation 2 over each load block and printing results at each print interval requested. This output consists of values for the most pertinent parameters which are valid at the cycle printed out. If the surface flaw correction is not used, M_k and Q from Equation 14 are set equal to unity.

In the course of the calculations, the denominator of Equation 2 is monitored to determine the cycle at which it becomes negative. Since it is possible for the denominator to go negative during an integration interval, the program sets an indicator in the integration routine and returns to the CRACKS program. Here the variables are reset to the values immediately before the denominator became negative. The program then uses these values as starting values and reduces the integration interval. The program then proceeds as before until the denominator again goes negative. This process is repeated until the integration interval is reduced to one cycle. When the denominator goes negative for this integration interval, the cycle number at the onset of instability is available. The final values are then printed out and identified. A similar procedure is followed when using Equation 1 except that the instability criterion becomes K_{max} greater than nine-tenths K_c .

SECTION IV

SUMMARY

An automated analysis for determining crack growth in cyclic loaded structures under variable amplitude loading has been described. In Appendix II an illustrative problem has been presented and the results compared with published data. The results show the program in close agreement with the analytical results and conservative in comparison with the experimental results.

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APPENDIX I
PROGRAM SOURCE LISTING

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$IBFTC CRACKS M94,XR7,DECK          CRAC0000
C                                         CRAC0001
C                                         CRAC0002
C                                         CRAC0003
C                                         CRAC0004
C                                         CRAC0005
C                                         CRAC0006
C                                         CRAC0007
C                                         CRAC0008
C                                         CRAC0009
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C                                         CRAC0011
C                                         CRAC0012
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C                                         CRAC0055
C                                         CRAC0056
C                                         CRAC0057
C                                         CRAC0058
C                                         CRAC0059
C                                         CRAC0060
C                                         CRAC0061

C                                         CRACKS

C                                         A FORTRAN IV COMPUTER PROGRAM FOR CRACK PROPAGATION ANALYSIS.

C                                         THIS PROGRAM IS BASED ON THEORY DEVELOPED IN A PAPER APPEARING IN
C                                         THE 'JOURNAL OF BASIC ENGINEERING' SEPTEMBER 1967, PAGES 459-464,
C                                         ENTITLED

C                                         'NUMERICAL ANALYSIS OF CRACK PROPAGATION IN CYCLIC-LOADED
C                                         STRUCTURES', R.G.FORMAN, V.E.KEARNEY, R.M.ENGLE

C                                         THE PROGRAM ACCEPTS EITHER FORMAN'S EQUATION OR PARIS' EQUATION

C                                         FORMAN'S EQUATION

C                                         DA/DN = C(DELTA K)**N/((1-R)KSUBC-DELTA K)

C                                         PARIS' EQUATION

C                                         DA/DN = C(DELTA K)**N

C                                         WHERE

C                                         DELTA K = (DELTA T) * SQRT(PI*A) * BETA

C                                         OR - FOR NASA DATA -

C                                         DELTA K = (DELTA T) * SQRT(A) * BETA

C                                         AND

C                                         DELTA T = (SIGMA MAX)-(SIGMA MIN)
C                                         BETA = COMBINATION OF CORRECTION FACTORS.

C                                         INPUT

C                                         CARD(S)  COLUMNS FORMAT      NAME      DESCRIPTION
C                                         1        1-80    14A6       TITLE      ANY DESCRIPTIVE INFORMATION
C                                         2        1-6     A6         EQN       'PARIS'-USE PARIS' EQUATION.
C                                         2        1-6     A6         EQN       'FORMAN'-USE FORMAN'S EQUATION.
C                                         2        1-6     A6         EQN       'NASAP'-USE PARIS' EQUATION
C                                         2        1-6     A6         EQN       WITH NASA DELTA K.
C                                         2        1-6     A6         EQN       'NASAF'-USE FORMAN'S EQUATION
C                                         2        1-6     A6         EQN       WITH NASA DELTA K.
C                                         2        7-10    4X         SKIP      SKIP 4 SPACES
C                                         2        11-52   7A6        MATID     MATERIAL ID.ANY INFORMATION
C                                         3        1-10    4E10.0     C         MATERIAL CONSTANT IN EQUATIONS
C                                         3        11-20   4E10.0     SMALLN    EXPONENT IN EQUATIONS
C                                         3        21-30   4E10.0     KSUBC     CRITICAL STRESS INTENSITY FACTOR
C                                         3        31-40   4E10.0     SIGMAY    YIELD STRESS
C                                         4        1-10    2E10.0     AZERO     INITIAL HALF CRACK LENGTH
C                                         4        11-20   2E10.0     AMAX      MAXIMUM CRACK LENGTH ALLOWED
C                                         5        1-4     A4         BETAL     'BETA'-LABEL FOR CORRECTION
C                                         5        5       11         I         FACTOR CARDS
C                                         5        5       11         I         CODE FOR CORRECTION FACTORS

```

C 6-10 5X 5E10.0 BI FIVE BLANKS CRAC0062
C 11-20 2E10.0 BI VARIABLE NEEDED FOR CORRECTION CRAC0063
C FACTOR CRAC0064
C 21-30 BII VARIABLE NEEDED FOR CORRECTION CRAC0065
C FACTOR CRAC0066
C CRAC0067
C ***** THE VARIABLES, BI AND BII, TAKE ON DIFFERENT MEANINGS FOR EACH BETACRAC0068
C CRAC0069
C 1 CORRECTION BI BII CRAC0070
C CRAC0071
C 1 CONSTANT CONSTANT 0. CRAC0072
C 2 FINITE WIDTH PLATE WIDTH 0. CRAC0073
C 3 TABULAR CHARACTERISTIC NUMBER OF POINTS CRAC0074
C LENGTH IN TABLE(NPTS) CRAC0075
C CRAC0076
C ***** THERE WILL BE 'NPTS' CARDS TO DEFINE THE TABLE. CRAC0077
C CRAC0078
C 1-10 2E10.0 AOVERB A/B RATIOS FOR TABLE CRAC0079
C 11-20 BETATB CORRESPONDING 'BETA' VALUES CRAC0080
C CRAC0081
C 4 SURFACE FLAW FLAW MATERIAL CRAC0082
C HALF-WIDTH THICKNESS CRAC0083
C 0 END OF CORRECTIONS CRAC0084
C CRAC0085
C ***** THE 'BETAO' CARD MUST ALWAYS BE PRESENT. IF THERE ARE SEVERAL CRAC0086
C CORRECTION FACTORS, IT MUST BE THE LAST 'BETA' CARD. IF NO CORRECTIONCRAC0087
C FACTOR CARDS ARE USED, 'BETAO' MUST STILL BE PRESENT. CRAC0088
C CRAC0089
C CRAC0090
C 6 1-10 E10.0 NZERO INITIAL CYCLE NUMBER CRAC0091
C 11-20 110 NFLITE REPEAT SPECTRUM 'NFLITE' TIMES. CRAC0092
C CRAC0093
C 7 1-5 A5 LOADS LABEL FOR FORM OF INPUT SPECTRUMCRAC0094
C 'SIGMA'-READ CARD(S) 9. CRAC0095
C 'RANGE'-READ CARD(S) 10. CRAC0096
C CRAC0097
C 8 1-5 A5 LABEL FIVE CHARACTERS CRAC0098
C 6-15 5E10.0 SIGMAX MAXIMUM STRESS CRAC0099
C 16-25 SIGMIN MINIMUM STRESS CRAC0100
C 26-35 CYCLES NO.CYCLES IN LOAD BLOCK CRAC0101
C 36-45 NINT INTEGRATION INTERVAL IN CYCLES CRAC0102
C IF NINT=0, SET NINT=CYCLES. CRAC0103
C 46-55 NPRINT PRINT INTERVAL IN CYCLES CRAC0104
C IF NPRINT=0, SET NPRINT=NINT. CRAC0105
C CRAC0106
C ***** A MAXIMUM OF 1000 LOAD CARDS IS PERMITTED.
C ***** GO TO CARD 10. CRAC0107
C 9 1-5 A5 LABEL FIVE CHARACTERS CRAC0108
C 6-15 5E10.0 DELTAT DELTA SIGMA(SIGMAX-SIGMIN) CRAC0109
C 16-25 K STRESS RATIO(SIGMIN/SIGMAX) CRAC0110
C 26-35 CYCLES NO.CYCLES IN LOAD BLOCK CRAC0111
C 36-45 NINT INTEGRATION INTERVAL IN CYCLES CRAC0112
C IF NINT=0, SET NINT=CYCLES. CRAC0113
C 46-55 NPRINT PRINT INTERVAL IN CYCLES CRAC0114
C IF NPRINT=0, SET NPRINT=NINT. CRAC0115
C CRAC0116
C ***** A MAXIMUM OF 1000 LOAD CARDS IS PERMITTED.
C CRAC0117
C 10 1-5 A3 END 'END'-TERMINATES PROBLEM INPUT. CRAC0118
C CRAC0119
C INTEGER BLK,END CRAC0120
C REAL NZERO,NINT,NPRINT,NFINAL,NN,NDEL,NSTRT,NWRITE CRAC0121
C REAL NASAF,NASAP CRAC0122
C REAL KSUBC,KMAX,MSUBK CRAC0123

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COMMON /DATA/ B(9),C,SMALLN,DELTAK,KMAX,KSUBC,NPTS,JJ,SIGMAY,EQN, CRAC0124
1      IPRC,THICK,AZERO,AMAX,Q,BETA(9),IND(9),PHI,RATIO,SMALLC CRAC0125
COMMON/CORFAC/TSUBA(1000),R(1000),AOVERB(100),BETATB(100),MSUBK CRAC0126
COMMON/STOP/ISTOP,ISTOPF,IN,AI,DX1,IDX CRAC0127
DIMENSION SIGMAX(1000),SIGMIN(1000),CYCLES(1000),NFINAL(1000), CRAC0128
1      NINT(1000),NPRINT(1000),TITLE(14) CRAC0129
DIMENSION LAB(1000),MATID(7) CRAC0130
DATA END,LOAD2 /5HEND ,6HRANGE / CRAC0131
DATA PARIS,FORMAN /6HPARIS ,6HFORMAN/ CRAC0132
DATA NASAP,NASAF /6HNASAP ,6HNASAF / CRAC0133
C
C      READ PROBLEM SPECIFICATIONS
C
10 READ(5,330) TITLE
  WRITE(6,400) TITLE
  READ(5,340) EQN,MATID
  READ(5,350) C,SMALLN,KSUBC,SIGMAY
  WRITE(6,410) MATID,C,SMALLN,KSUBC,SIGMAY
  READ(5,350) AZERO,AMAX
  IF(AMAX.LE.0.) AMAX=1.0E37
  WRITE(6,420) AZERO
  IPRC=0
  DO 20 I=1,9
  IND(I)=0
20 BETA(I)=1.0
  IF(EQN.EQ.PARIS.OR.EQN.EQ.FORMAN) WRITE(6,650)
  IF(EQN.EQ.NASAP.OR.EQN.EQ.NASAF ) WRITE(6,660)
C
C      READ CORRECTION FACTOR SPECIFICATIONS
C
30 READ(5,370) BETAL,I,BI,B1I
  IF(I.EQ.0) GO TO 100
  GO TO (40,50,60,70,80,80,80,80,80),I
40 BETA(I)=BI
  WRITE(6,450) BETA(I)
  IND(I)=I
  GU TU 30
50 IND(I)=I
  B(I)=BI
  WRITE(6,610) B(I)
  GO TO 30
60 B(I)=BI
  IND(I)=I
  NPTS=B1I+0.5
  WRITE(6,620) B(I)
  IF(NPTS.LE.0.OR.NPTS.GT.100) GO TO 90
  READ(5,390) (AOVERB(I),BETATB(I),I=1,NPTS)
  WRITE(6,460)(AOVERB(I),BETATB(I),I=1,NPTS)
  GO TO 30
70 B(I)=BI
  THICK=B1I
  RATIO=AZERO/(2.0*B(I))
  SMALLK=(B(I)**2-AZERO**2)/B(I)**2
  CK=1.-SMALLK**2
  CKSQD=CK*CK
  CALL CELI2(PHI0,SMALLK,1.0,CKSQD,IER)
  PHI=PHI0
  IPRC=1
  IND(I)=I
  WRITE(6,630) B(I),THICK
  GO TO 30
80 CONTINUE

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      GO TO 30                                CRAC0186
  90 WRITE(6,640)                            CRAC0187
      GO TO 10                                CRAC0188
C
C      READ CONTROL SPECIFICATIONS          CRAC0189
C
  100 READ(5,360) NZERO,NFLITE               CRAC0192
      WRITE(6,430) NZERO                      CRAC0193
      WRITE(6,440) NFLITE                     CRAC0194
C
C      READ LOAD SPECTRUM SPECIFICATIONS     CRAC0195
C
      READ(5,330) LOADS                       CRAC0196
      BLK=1                                    CRAC0197
      IF(LOADS.EQ.LOAD2) GO TO 140            CRAC0200
C
C      LOAD SPECTRUM IN TERMS OF MAX AND MIN STRESSES CRAC0201
C
      READ(5,380) LAB(BLK),SIGMAX(BLK),SIGMIN(BLK),CYCLES(BLK),NINT(BLK) CRAC0204
  1,           NPRINT(BLK)                   CRAC0205
C
C      INTEGRATION INTERVAL CANNOT EXCEED BLOCK SIZE    CRAC0206
C
      IF(NINT(BLK).GT.CYCLES(BLK)) NINT(BLK)=CYCLES(BLK) CRAC0209
      IF(NINT(BLK).EQ.0.) NINT(BLK)=CYCLES(BLK)          CRAC0210
      NFINAL(BLK)=NZERO+CYCLES(BLK)                  CRAC0211
  110 BLK=BLK+1                               CRAC0212
      READ(5,380) LAB(BLK),SIGMAX(BLK),SIGMIN(BLK),CYCLES(BLK),NINT(BLK) CRAC0213
  1,           NPRINT(BLK)                   CRAC0214
      IF(LAB(BLK).EQ.END) GO TO 120            CRAC0215
C
C      INTEGRATION INTERVAL CANNOT EXCEED BLOCK SIZE    CRAC0216
C
      IF(NINT(BLK).GT.CYCLES(BLK)) NINT(BLK)=CYCLES(BLK) CRAC0219
      IF(NINT(BLK).EQ.0.) NINT(BLK)=CYCLES(BLK)          CRAC0220
      NFINAL(BLK)=NFINAL(BLK-1)+CYCLES(BLK)            CRAC0221
      IF(NPRINT(BLK).EQ.0.) NPRINT(BLK)=NINT(BLK)        CRAC0222
      GO TO 110                                CRAC0223
  120 BLK=BLK-1                               CRAC0224
      WRITE(6,470)                            CRAC0225
      LINE=0                                  CRAC0226
      DO 130 I=1,BLK                         CRAC0227
      WRITE(6,480)LAB(I),I,CYCLES(I),NFINAL(I),SIGMAX(I),SIGMIN(I),
  1           NINT(I)                      CRAC0228
C
C      THEORY DOES NOT RECOGNIZE EFFECTS OF NEGATIVE LOADING   CRAC0229
C
      IF(SIGMIN(I).LT.0.)SIGMIN(I)=0.          CRAC0231
      LINE=LINE+1                            CRAC0232
      IF(LINE.GT.55) LINE=0                  CRAC0233
      IF(LINE.EQ.0) WRITE(6,470)             CRAC0234
C
C      CONVERT STRESSES TO RANGE AND RATIO    CRAC0235
C
      TSUBA(I)=SIGMAX(I)-SIGMIN(I)          CRAC0236
      R(I)=SIGMIN(I)/SIGMAX(I)              CRAC0237
  130 CONTINUE                                CRAC0238
      GO TO 170                                CRAC0239
C
C      LOAD SPECTRUM IN TERMS OF STRESS RANGE AND STRESS RATIO CRAC0240
C
  140 READ(5,380) LAB(BLK),TSUBA(BLK),R(BLK),CYCLES(BLK),NINT(BLK), CRAC0241
      CRAC0242
      CRAC0243
      CRAC0244
      CRAC0245
      CRAC0246
      CRAC0247

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1           NPRINT(BLK)                               CRAC0248
C
C   INTEGRATION INTERVAL CANNOT EXCEED BLOCK SIZE    CRAC0249
C
C   IF(NINT(BLK).GT.CYCLES(BLK)) NINT(BLK)=CYCLES(BLK)  CRAC0250
C   IF(NINT(BLK).EQ.0.) NINT(BLK)=CYCLES(BLK)          CRAC0251
C   NFINAL(BLK)=NZERO+CYCLES(BLK)                     CRAC0252
C   IF(NPRINT(BLK).EQ.0.) NPRINT(BLK)=NINT(BLK)        CRAC0253
150  BLK=BLK+1                                     CRAC0254
      READ(5,380) LAB(BLK),TSURA(BLK),R(BLK),CYCLES(BLK),NINT(BLK),
      1           NPRINT(BLK)                         CRAC0255
      IF(LAB(BLK).EQ.END) GO TO 160                 CRAC0256
C
C   INTEGRATION INTERVAL CANNOT EXCEED BLOCK SIZE    CRAC0257
C
C   IF(NINT(BLK).GT.CYCLES(BLK)) NINT(BLK)=CYCLES(BLK)  CRAC0258
C   IF(NINT(BLK).EQ.0.) NINT(BLK)=CYCLES(BLK)          CRAC0259
C   NFINAL(BLK)=NFINAL(BLK-1)+CYCLES(BLK)            CRAC0260
C   IF(NPRINT(BLK).EQ.0.) NPRINT(BLK)=NINT(BLK)        CRAC0261
C   GO TO 150                                       CRAC0262
160  BLK=BLK-1                                     CRAC0263
170  WRITE(6,500)                                 CRAC0264
      LINE=0                                         CRAC0265
      DO 160 I=1,BLK                                CRAC0266
      WRITE(6,490)LAB(I),I,CYCLES(I),NFINAL(I),TSUBA(I),R(I),NINT(I)
C
C   THEORY DOES NOT RECOGNIZE EFFECTS OF/NEGATIVE LOADING  CRAC0267
C
C   IF(R(I).LT.0.) R(I)=0.                           CRAC0271
C   LINE=LINE+1                                     CRAC0272
C   IF(LINE.GT.55) LINE=0                          CRAC0273
C   IF(LINE.EQ.0) WRITE(6,500)                      CRAC0274
180  CONTINUE                                     CRAC0275
      ISTOP=0                                       CRAC0276
      ISTOPF=0                                      CRAC0277
      IDX=0                                         CRAC0278
      DX1=0.                                        CRAC0279
      A=AZERO                                       CRAC0280
      A1=AZERO                                      CRAC0281
C
C   REPEAT INPUT SPECTRUM NFLITE TIMES             CRAC0282
C
C   DO 320 NFLT=1.:FLITE                          CRAC0283
      WRITE(6,510) :FLT,A                         CRAC0284
      IF(EQN.EQ.PARIS.OR.EQN.EQ.NASAP) GO TO 190
      WRITE(6,520)
      GO TO 200
190  WRITE(6,530)
200  IN=NZERO                                     CRAC0285
      NN=NZERO                                      CRAC0286
      LINES=0                                       CRAC0287
      IF(IPRC.EQ.0) WRITE(6,560)                  CRAC0288
      IF(IPRC.NE.0) WRITE(6,570)
C
C   DO LOOP FOR LOAD BLOCKS                       CRAC0289
C
C   DO 310 JJ=1,BLK                                CRAC0290
      JJJ=1                                         CRAC0291
      DX=NINT(JJ)                                    CRAC0292
210  IF(JJ.GT.1) GO TO 220                        CRAC0293
      NSTRT=NZERO                                    CRAC0294
      GO TO 230                                       CRAC0295
      CRAC0296
      CRAC0297
      CRAC0298
      CRAC0299
      CRAC0300
      CRAC0301
      CRAC0302
      CRAC0303
      CRAC0304
      CRAC0305
      CRAC0306
      CRAC0307
      CRAC0308
      CRAC0309

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220 NSTRT=NFINAL(JJ-1) CRAC0310
230 NWRITE=NSTART+FLOAT(JJJ)*NPRINT(JJ) CRAC0311
    IF((NN+NINT(JJ)).LE.NFINAL(JJ)) GO TO 250 CRAC0312
    NDEL=NN+NINT(JJ)-NFINAL(JJ) CRAC0313
    DX= NINT(JJ)-NDEL CRAC0314
    IF(ISTOPF.EQ.0) GO TO 250 CRAC0315
240 IF(DX1.GT.1.00) ISTOPF=0 CRAC0316
    DX=DX1 CRAC0317
    NN=IN CRAC0318
    A=A1 CRAC0319
    ISTOP=0 CRAC0320
250 CYC=NN CRAC0321
C
C      INTEGRATE OVER ONE INTERVAL CRAC0322
C
C      CALL RK1DES(CYC,A,DX) CRAC0323
    IF(ISTOPF.EQ.1) GO TO 240 CRAC0324
    IF(ISTOP.NE.0) GO TO 10 CRAC0325
    NN=CYC CRAC0326
    IF(NN.NE.NWRITE) GO TO 280 CRAC0327
C
C      PRINT RESULTS AT EACH PRINT INTERVAL CRAC0328
C
C      CALL F(CYC,A,DADN) CRAC0329
    IF(IPRC.NE.0) GO TO 260 CRAC0330
    WRITE(6,540) NN,A,DADN,DELTAK,KMAX,MSUBK,Q CRAC0331
    GO TO 270 CRAC0332
260 WRITE(6,550) NN,A,SMALLC,DADN,DELTAK,KMAX,MSUBK,Q CRAC0333
270 JJJ=JJJ+1 CRAC0334
    LINES=LINES+1 CRAC0335
    IF(LINES.EQ.50)LINES=0 CRAC0336
    IF(LINES.EQ.0.AND.EQN.EQ.FORMAN) WRITE(6,580) CRAC0337
    IF(LINES.EQ.0.AND.EQN.EQ.NASAF ) WRITE(6,580) CRAC0338
    IF(LINES.EQ.0.AND.EQN.EQ.PARIS) WRITE(6,590) CRAC0339
    IF(LINES.EQ.0.AND.EQN.EQ.NASAP) WRITE(6,590) CRAC0340
    IF(LINES.EQ.0.AND.IPRC.EQ.0) WRITE(6,560) CRAC0341
    IF(LINES.EQ.0.AND.IPRC.NE.0) WRITE(6,570) CRAC0342
    IF(NN.EQ.NFINAL(JJ)) GO TO 310 CRAC0343
    GO TO 210 CRAC0344
C
C      CHECK FOR END OF LOAD BLOCK AND PRINT RESULTS CRAC0345
C
C      280 IF(NN.LT.NFINAL(JJ)) GO TO 210 CRAC0346
    CALL F(CYC,A,DADN) CRAC0347
    IF(IPRC.NE.0) GO TO 290 CRAC0348
    WRITE(6,540) NN,A,DADN,DELTAK,KMAX,MSUBK,Q CRAC0349
    GO TO 300 CRAC0350
290 WRITE(6,550) NN,A,SMALLC,DADN,DELTAK,KMAX,MSUBK,Q CRAC0351
300 LINES=LINES+1 CRAC0352
    IF(LINES.EQ.50)LINES=0 CRAC0353
    IF(LINES.EQ.0.AND.EQN.EQ.FORMAN) WRITE(6,580) CRAC0354
    IF(LINES.EQ.0.AND.EQN.EQ.NASAF ) WRITE(6,580) CRAC0355
    IF(LINES.EQ.0.AND.EQN.EQ.PARIS) WRITE(6,590) CRAC0356
    IF(LINES.EQ.0.AND.EQN.EQ.NASAP) WRITE(6,590) CRAC0357
    IF(LINES.EQ.0.AND.IPRC.EQ.0) WRITE(6,560) CRAC0358
    IF(LINES.EQ.0.AND.IPRC.NE.0) WRITE(6,570) CRAC0359
310 CONTINUE CRAC0360
    GROWTH=A-AZERO CRAC0361
    WRITE(6,600) NFLT,A,GROWTH CRAC0362
320 CONTINUE CRAC0363
C
C      LOOK FOR ANOTHER PROBLEM CRAC0364
C

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GC TC 1C CRAC0372
330 FORMAT(14A6) CRAC0373
340 FCRMAT(A6,4X,7A6) CRAC0374
350 FORMAT(6E1C,C) CRAC0375
360 FORMAT(E12.0,11G) CRAC0376
370 FORMAT(A4,I1,5X,2E10.C) CRAC0377
380 FORMAT(A5,5E10.C) CRAC0378
390 FCRMAT(2E10.C) CRAC0379
400 FORMAT(1H11CX14A6) CRAC0380
410 FORMAT(1HC1CX18HMATERIAL CONSTANTS6X7A6/11X3HC =E16.8,5X8H$MALLN =CRAC0381
1F5.2,5X7H$SUBC =E16.8,5X14HYIELD STRESS =E16.8) CRAC0382
420 FORMAT(1HC1CX27HINITIAL HALF CRACK LENGTH = E16.8) CRAC0383
430 FORMAT(1HC1CX22HINITIAL CYCLE NUMBER =F11.3) CRAC0384
440 FCRMAT(1HC1CX21HREPEAT INPUT SPECTRUM,15,7H TIMES ) CRAC0385
450 FCRMAT(1HC1CX34H$\BETA(1)-CONSTANT CORRECTION FACTOR /19X9HBETA(1) =CRAC0386
1 E16.8) CRAC0387
460 FCRMAT(1F013X3H/A/B16X7HBETA(3)//(8XE15.8,5XE15.8)) CRAC0388
470 FORMAT(1H112X4HLCAD11X9HNUMBER OF11X9HNUMBER OF18X5HSIGMA20X5HSIGMCRAC0389
1A14X11H-INTEGRATION/13X5HBLOCK10X10HCYCLES PER1CX8HCYCLE AT19X3HMAXCRAC0390
222X3HMIN16X8HINTERVAL/28X1CHLOAD BLOCK10X12HEND OF BLOCK59X8H(CYCLCRAC0391
3ES)//) CRAC0392
480 FCRMAT(2XA5,6X15,10XF11.3,10XF11.3,15XF10.2,13XF10.2,10XF11.3) CRAC0393
490 FORMAT(2XA5,6X15,10XF11.3,10XF11.3,15XF10.2,16XF6.3, 10XF11.3) CRAC0394
500 FORMAT(1H112X4HLCAD11X9HNUMBER OF11X9HNUMBER CF18X5HDETA22X1HR16XCRAC0395
111H-INTEGRATION/13X5H8LCC1CX10HCYCLES PER10X8HCYCLE AT19X5HSIGMA39CRAC0396
2X8HINTERVAL/28X1CHLLAD BLOCK10X12HEND CF BLOCK59X8H(CYCLES)//) CRAC0397
510 FGRMAT(1H15X35HCRACK LENGTH AT BEGINNING OF FLIGHT 15,3H ISF10.5/)CRAC0398
520 FCRMAT(1H04CX5CHCRACK PRCPAGATION ANALYSIS USING FORMAN'S EQUATIONCRAC0399
1 /44X44HDA/DN=C*(DELTA K)**N/((1-R)*KSUBC-DELTA K) ) CRAC0400
530 FORMAT(1H041X48HCRACK PRCPAGATION ANALYSIS USING PARIS' EQUATION /CRAC0401
1 55X23HDA/DN=C*(DELTA K)**N ) CRAC0402
540 FORMAT(1XF11.3,13XF9.5,13XE15.8,13XF10.2,16XF10.2,4XF5.3,5XF6.3) CRAC0403
550 FORMAT(1XF11.3,13XF9.5,2XF9.5,2XE15.8,13XF10.2,16XF10.2,4XF5.3,5X
1 F6.3) CRAC0404
560 FORMAT(1HC3X5HCYCLE20X1HA22X5HDA/DN21X7HDETA K19X5HK MAX6X5HMSUBKCRAC0406
1 8X1FC//) CRAC0407
570 FORMAT(1H03X5HCYCLE20X1HA1CX1HC11X5HDA/DN21X7HDETA K19X5HK MAX
1 6X5HMSUBK8X1FG//) CRAC0408
580 FORMAT(1H14X5CHCRACK PRCPAGATION ANALYSIS USING FORMAN'S EQUATIONCRAC0410
1 /44X44HDA/DN=C*(DELTA K)**N/((1-R)*KSUBC-DELTA K) ) CRAC0411
590 FORMAT(1H141X48HCRACK PRCPAGATION ANALYSIS USING PARIS' EQUATION /CRAC0412
1 55X23HDA/DN=C*(DELTA K)**N ) CRAC0413
600 FORMAT(1H01CX36HCRACK LENGTH AT END OF FLIGHT NUMBER 15,3H ISF10.5CRAC0414
1/ 11X21HTOTAL CRACK GROWTH IS F10.5)
610 FORMAT(1HC1CX38H$\BETA(2)-FINITE WIDTH CORRECTION FACTOR /19X42HBETACRAC0416
1(2) = SQRT(2/(PI*A/B)*TAN(PI*(A/B)/2)) /19X12HWHERE....B = E16.8) CRAC0417
620 FORMAT(1HC1CX32H$\BETA(3)-TABULAR FUNCTION OF A/B /19X12HWHERE....B
1 = E16.8) CRAC0418
630 FORMAT(1HC1CX39H$\BETA(4)-SURFACE CRACK CORRECTION FACTOR /
1 19X51H$\BETA(4)=1.1/SQRT(PHI)**2-C.212*(DELTA T/SIGMA Y)**2)/ CRAC0420
219X51HWHERE....PHI=E(K,PI/2),K=((B**2-A**2)/B**2) AND B = E16.8 /CRAC0421
324X62H$E(K,PI/2) IS THE COMPLETE ELLIPTIC INTEGRAL QF. THE SECND KICRAC0423
4ND/15X26HMATERIAL THICKNESS.....T = E16.8) CRAC0424
640 FORMAT(1HC1CX33H$INPLT ERROR,NPTS=0,OR NPTS.GT.100 ) CRAC0425
650 FORMAT(1HC1CX36H$CORRECTION FACTORS USED FOR DELTA K //11X60HDELTACRAC0426
1 K =(DELTA T)*SQRT(PI*A)*$\BETA(1)*$\BETA(2)*...$\BETA(I) )CRAC0427
660 FGRMAT(1HC1CX36H$CORRECTION FACTORS USED FOR DELTA K //11X60HDELTACRAC0428
1 K =(DELTA T)*SQRT( A )*$BETA(1)*$BETA(2)*...$BETA(I) )CRAC0429
ENC CRAC0430

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$IBFTC DADN M94,XR7,DECK                               DADN0009
SUBROUTINE F(N,A,DADN)                                 DADN0001
COMMON /DATA/ B(9),C,SMALLN,DELTAK,KMAX,KSUBC,NPTS,JJ,SIGMAY,EQN,   DADN0002
1          IPRC,THICK,AZERO,AMAX,Q,BETA(9),IND(9),PHI,RATIO,SMALLC   DADN0003
COMMON/CORFAC/TSUBA(1000),R(1000),AOVERB(100),BETATB(100),MSUBK   DADN0004
COMMON/STOP/ISTOP,ISTOPF,IN,A1,DX1,IDX                  DADN0005
COMMON / MKCURV / MK(1000)                            DADN0006
REAL MK,MSUBK,MSUBK1                                DADN0007
REAL NASAF,NASAP                                     DADN0008
REAL KSUBC,N,KMAX,KMAX1                            DADN0009
REAL KMIN                                         DADN0010
REAL IN,INN                                         DADN0011
DATA PI/3.1415926/                                    DADN0012
DATA PARIS,FORMAN /6HPARIS ,6HFORMAN/             DADN0013
DATA NASAP,NASAP /6HNASAP ,6HNASAF /            DADN0014
BETAT=1.0                                         DADN0015
MSUBK=1.0                                         DADN0016
Q=0.0                                           DADN0017
SMALLC=A/(2.0*RATIO)                           DADN0018
DO 70 I=1,9                                         DADN0019
J=IND(I)                                         DADN0020
IF(J.EQ.0) GO TO 70                               DADN0021
GO TO (60,10,20,40,50,50,50,50,50),J           DADN0022
10 IF(IPRC.NE.C) GO TO 70                         DADN0023
SMALLK=A/B(J)                                     DADN0024
IF(SMALLK.GT.1.0) GO TO 320                      DADN0025
BETA(J)=SQRT(2.0/(PI*SMALLK)*TAN(PI*SMALLK/2.0)) DADN0026
GO TO 60                                         DADN0027
20 SMALLK=A/B(J)                                   DADN0028
30 BETA(J)=TBLKUP(AOVERB,BETATB,NPTS,100,SMALLK) DADN0029
GO TO 60                                         DADN0030
40 ATRANS=THICK-((KMAX/SIGMAY)**2)/(2.0*PI)       DADN0031
IF(A.GE.ATRANS) GO TO 340                        DADN0032
AOVERT = A/THICK                                  DADN0033
MSUBK = TRP2(MK,AOVERT,RATIO,1)                 DADN0034
BETA(J)=1.1*MSUBK                                DADN0035
GO TO 60                                         DADN0036
50 CONTINUE                                       DADN0037
60 BETAT=BETAT*BETA(J)                          DADN0038
70 CONTINUE                                       DADN0039
IF(IPRC.EQ.J) GO TO 80                          DADN0040
C      Q = SHAPE FACTOR FOR SURFACE CRACKS        DADN0041
C      SIGMAX=TSUBA(JJ)/(1.0-R(JJ))              DADN0042
C      SIGMIN=SIGMAX-TSUBA(JJ)                    DADN0043
C      QMAX=PHI**2-0.212*(SIGMAX/SIGMAY)**2       DADN0044
C      Q=QMAX                                      DADN0045
C      QMIN=PHI**2-0.212*(SIGMIN/SIGMAY)**2       DADN0046
80 IF(EQN.EQ.NASAP.OR.EQN.EQ.NASAF) GO TO 100    DADN0047
C      DELTA K USING FORMAN'S FORM AND CONSTANTS   DADN0048
C      IF(IPRC.NE.C) GO TO 90                     DADN0049
C      DELTAK=TSUBA(JJ)*SQRT(PI*A)*BETAT          DADN0050
C      KMAX=DELTAK/(1.0-R(JJ))                   DADN0051
C      GO TO 120                                    DADN0052
90 KMAX=SIGMAX*SQRT(PI*A/QMAX)*BETAT          DADN0053
KMIN=SIGMIN*SQRT(PI*A/QMIN)*BETAT          DADN0054
DELTAK=KMAX-KMIN                                DADN0055
GO TO 120                                         DADN0056
C

```

```

C      DELTA K USING HUDSON'S FORM AND CONSTANTS          DADN0062
C                                                               DADN0063
100 IF(IPRC.NE.0) GO TO 110                               DADN0064
      DELTAK=TSUBA(JJ)*SQRT(A)*BETAT                   DADN0065
      KMAX=DELTAK/(1.0-R(JJ))                           DADN0066
      GO TO 120                                         DADN0067
110 KMAX=SIGMAX*SQRT( A /QMAX)*BETAT                  DADN0068
      KMIN=SIGMIN*SQRT( A /QMIN)*BETAT                 DADN0069
      DELTAK=KMAX-KMIN                                    DADN0070
120 IF(A.GT.AMAX) GO TO 360                            DAUN0071
      IF(EQN.EQ.PARIS.OR.EQN.EQ.NASAP) GO TO 130        DADN0072
      DENOM=(1.0-R(JJ))*KSUBC-DELTAK                   DADN0073
      IF(DENOM.LE.0.) GO TO 150                         DADN0074
      GO TO 140                                         DADN0075
130 DELKC=0.9*KSUBC-KMAX                                DADN0076
      IF(DELKC.LE.0.) GO TO 150                         DADN0077
      DENOM=1.0                                         DADN0078
140 DADN=(C*DELTAK**SMALLN)/DENOM                     DADN0079
      IN=N                                              DADN0080
      GO TO 290                                         DADN0081
150 ISTOP=1                                           DADN0082
      IF(ISTOPF.NE.0) GO TO 210                         DADN0083
      ISTCPF=ISTOPF+1                                    DADN0084
      IF(IDX.NE.0) GO TO 180                           DADN0085
      INN=N                                             DADN0086
      IF(EQN.EQ.FORMAN.OR.EQN.EQ.NASAF) WRITE(6,160) INN DADN0087
160 FORMAT(1H036H((1-R)KSUBC-DELTAK) WENT NEGATIVE ATF11.3,7H CYCLES /DADN0088
      11H010X37HBEGIN SEARCH FOR MORE ACCURATE VALUES /11X15HSTARTING VADADN0089
      2LUES//)                                         DADN0090
      IF(EQN.EQ.PARIS.OR.EQN.EQ.NASAP) WRITE(6,170)INN DADN0091
170 FORMAT(1H037HK MAX BECAME GREATER THAN .9*KSUBC ATF11.3,7H CYCLES/DADN0092
      11H01CX37HBEGIN SEARCH FOR MORE ACCURATE VALUES /11X15HSTARTING VADADN0093
      2LUES//)                                         DADN0094
      GO TO 200                                         DADN0095
180 WRITE(6,190) IDX                                     DADN0096
190 FORMAT(1H010X16HVALUES FOR DX = 14,7H CYCLES //) DADN0097
200 WRITE(6,220) IN,A1,DA1,DEL1,KMAX1,MSUBK1,Q1       DADN0098
      GO TO 240                                         DADN0099
210 WRITE(6,230)
      WRITE(6,220) IN,A1,DA1,DEL1,KMAX1,MSUBK1,Q1       DADN0100
220 FORMAT(2XF11.3,13XF9.5,13XE15.8,13XF10.2,16XF10.2,4XF5.3,5XF6.3) DADN0102
230 FORMAT(1H010X41H*****VALUES AT UNSET OF INSTABILITY***** //) DADN0103
      ISTOPF=2                                         DADN0104
      RETURN                                         DADNC105
240 DELTAN=N-IN                                       DADN0106
      IF(DELTAN.LE.1.) GO TO 210                         DADN0107
      NDEL=ALOG10(DELTAN)                                DADN0108
      IF(NDEL.EQ.0) GO TO 250                           DADN0109
      IF(NDEL.GT.6) GO TO 300                           DADN0110
      GO TO (250,250,250,260,270,280),NDEL           DADN0111
250 DX1=1.                                           DADN0112
      IDX=DX1+0.5                                      DADN0113
      RETURN                                         DADN0114
260 DX1=10.                                          DADN0115
      IDX=DX1+0.5                                      DADN0116
      RETURN                                         DADN0117
270 DX1=100.                                         DADN0118
      IDX=DX1+0.5                                      DADN0119
      RETURN                                         DADN0120
280 DX1=1000.                                         DADN0121
      IDX=DX1+0.5                                      DADN0122
      RETURN                                         DADN0123

```

```

290 A1=A DADN0124
  DA1=DADN DADN0125
  DEL1=DELTAK DADN0126
  KMAX1=KMAX DADN0127
  Q1=Q DADN0128
  MSUBK1=MSUBK DADN0129
  RETURN DADN0130
  DADN0131
300 WRITE(6,310) DADN0132
310 FORMAT(1H06X101HSOMETHING IS RADICALLY WRONG.THE CRITICAL VALUE OF DADN0132
  1 N CAN ONLY BE DETERMINED WITHIN ONE MILLION CYCLES ) DADN0133
  1 STOPF=2 DADN0134
  RETURN DADN0135
  DADN0136
320 WRITE(6,330) DADN0137
330 FORMAT(1H075HCRACK LENGTH,A,IS GREATER THAN PLATE WIDTH,B.THIS IS DADN0137
  1PHYSICALLY IMPOSSIBLE. ) DADN0138
  GO TO 390 DADN0139
  DADN0140
340 AEFF=BETAT**2*ATRANS DADN0141
  WRITE(6,350) AEFF DADN0142
350 FORMAT(1X130(1H*)/35X41HTRANSITION TO A THROUGH CRACK OF LENGTH DADN0142
  1 F9.5,7H INCHES/1X130(1H*)) DADN0143
  IND(4)=0 DADN0144
  A=AEFF DADN0145
  IPRC=0 DADN0146
  GO TO 80 DADN0147
  DADN0148
360 WRITE(6,370) DADN0149
370 FORMAT(1H1130(1H*)/14X104HTHE CRACK GROWTH EXCEEDS THE MAXIMUM ALLOWED LENGTH. DADN0149
  EXAMINE THE PROBLEM FOR POSSIBLE REFORMULATION. /DADN0150
  21X130(1H*)) DADN0151
  WRITE(6,360) DADN0152
380 FORMAT(1H03X5HCVCLE20X1HA22X5HDA/DN21X7HDELTA K19X5HK MAX6X5HMSUBK DADN0153
  1 8X1HQ//) DADN0154
  WRITE(6,220) IN,A1,DA1,DEL1,KMAX1,MSUBK1,Q1 DADN0155
390 ISTUP=1 DADN0156
  STOPF=2 DADN0157
  RETURN DADN0158
  END DADN0159

```

```

SIBFTC RK1DES M94,XR7,DECK          RK1D0003
      SUBROUTINE RK1DES(X,Y,DX)        RK1D0001
      COMMON/STOP/ISTOP,ISTOPF,IN,A1,DX1,IDX   RK1D0002
10     X0=X                         RK1D0003
      X=X+DX                        RK1D0004
      H=DX                          RK1D0005
20     IF(ABS(H).GT.ABS(X-X0)) H=X-X0    RK1D0006
30     Y0=Y                         RK1D0007
      HT=H                         RK1D0008
      XT=X0                        RK1D0009
      RMAXP=1.E37                   RK1D0010
40     YT=Y0                        RK1D0011
      ASSIGN 50 TO K               RK1D0012
      GO TO 100                     RK1D0013
50     CONTINUE                      RK1D0014
60     YP=Y                         RK1D0015
70     HT=0.5*H                     RK1D0016
      ASSIGN 80 TO K               RK1D0017
      GO TO 100                     RK1D0018
80     CONTINUE                      RK1D0019
90     YT=Y                         RK1D0020
      XT=X0+HT                     RK1D0021
      ASSIGN 150 TO K              RK1D0022
100    CALL F(XT,YT,P0)            RK1D0023
      IF(ISTOP.NE.0) RETURN        RK1D0024
110    Y=YT+0.5*HT*P0             RK1D0025
      CALL F(XT+0.5*HT,Y,P1)       RK1D0026
      IF(ISTOP.NE.0) RETURN        RK1D0027
120    Y=YT+0.5*HT*P1             RK1D0028
      CALL F(XT+0.5*HT,Y,P2)       RK1D0029
      IF(ISTOP.NE.0) RETURN        RK1D0030
130    Y=YT+HT*P2                 RK1D0031
      CALL F(XT+HT,Y,P3)          RK1D0032
      IF(ISTOP.NE.0) RETURN        RK1D0033
140    Y=YT+HT*(P0+2.*(P1+P2)+P3)/6.  RK1D0034
      GO TO K,(50,80,150)         RK1D0035
150    RMAX=0.                      RK1D0036
160    RMAX=AMAX1(RMAX,0.07*ABS((Y-YP)/Y))  RK1D0037
      IF((RMAX.GT.1.E-06).AND.(RMAX.LT.RMAXP)) GO TO 170
      X0=X0+H                      RK1D0038
      IF(X0.EQ.X) RETURN           RK1D0039
      IF((RMAX.LT.1.E-07). OR.(RMAX.GT.RMAXP)) H=H+H
      GO TO 20                     RK1D0040
170    H=HT                         RK1D0041
      XT=X0                        RK1D0042
180    YP=YT                        RK1D0043
190    YT=Y0                        RK1D0044
      RMAXP=RMAX                   RK1D0045
      GO TO 70                     RK1D0046
      END                          RK1D0047
                                         RK1D0048
                                         RK1D0049

```

```
$IBFTC TBLKUP M94,XR7,DECK
FUNCTION TBLKUP(X,Y,N,NMAX,ARG)
DIMENSION X(NMAX),Y(NMAX)
DO 10 I=1,N
IF(X(I)-ARG) 10,20,20
10 CONTINUE
I=N
20 IF(I-1)30,30,40
30 I=2
40 SLOPE=(Y(I)-Y(I-1))/(X(I)-X(I-1))
TBLKUP=SLOPE*(ARG-X(I-1))+Y(I-1)
RETURN
END
```

```
TBLK0000
TBLK0001
TBLK0002
TBLK0003
TBLK0004
TBLK0005
TBLK0006
TBLK0007
TBLK0008
TBLK0009
TBLK0010
TBLK0011
TBLK0012
```

```

$IBFTC ELIP2 M94,XR7,DECK          ELIP0000
C                                         ELIP0001
C .....                               ELIP0002
C                                         ELIP0003
C                                         SUBROUTINE CELI2      ELIP0004
C                                         PURPOSE           ELIP0005
C                                         COMPUTES THE GENERALIZED COMPLETE ELLIPTIC INTEGRAL OF
C                                         SECOND KIND.        ELIP0006
C                                         USAGE             ELIP0007
C                                         CALL CELI2(RES,AV,A,B,IER)    ELIP0008
C                                         DESCRIPTION OF PARAMETERS   ELIP0009
C                                         RES - RESULT VALUE       ELIP0010
C                                         AK  - MODULUS (INPUT)     ELIP0011
C                                         A   - CONSTANT TERM IN NUMERATOR   ELIP0012
C                                         B   - FACTOR OF QUADRATIC TERM IN NUMERATOR   ELIP0013
C                                         IER - RESULTANT ERROR CODE WHERE   ELIP0014
C                                         IER=0 NO ERROR           ELIP0015
C                                         IER=1 AK NOT IN RANGE -1 TO +1   ELIP0016
C                                         REMARKS          ELIP0017
C                                         FOR AK = +1,-1 THE RESULT VALUE IS SET TO 1.E75 IF B IS   ELIP0018
C                                         POSITIVE, TO -1.E75 IF B IS NEGATIVE.   ELIP0019
C                                         SPECIAL CASES ARE   ELIP0020
C                                         K(K) OBTAINED WITH A = 1, B = 1   ELIP0021
C                                         E(K) OBTAINED WITH A = 1, B = CK*CK WHERE CK IS   ELIP0022
C                                         COMPLEMENTARY MODULUS.   ELIP0023
C                                         B(K) OBTAINED WITH A = 1, B = 0   ELIP0024
C                                         D(K) OBTAINED WITH A = 0, B = 1   ELIP0025
C                                         WHERE K, E, B, D DEFINE SPECIAL CASES OF THE GENERALIZED   ELIP0026
C                                         COMPLETE ELLIPTIC INTEGRAL OF SECOND KIND IN THE USUAL   ELIP0027
C                                         NOTATION, AND THE ARGUMENT K OF THESE FUNCTIONS MEANS   ELIP0028
C                                         THE MODULUS.   ELIP0029
C                                         SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED   ELIP0030
C                                         NONE          ELIP0031
C                                         METHOD          ELIP0032
C                                         DEFINITION      ELIP0033
C                                         RES=INTEGRAL((A+B*T*T)/(SQRT((1+T*T)*(1+(CK*T)**2))*(1+T*T)))   ELIP0034
C                                         SUMMED OVER T FROM 0 TO INFINITY.   ELIP0035
C                                         EVALUATION      ELIP0036
C                                         LANDENS TRANSFORMATION IS USED FOR CALCULATION.   ELIP0037
C                                         REFERENCE       ELIP0038
C                                         R.BULIRSCH, 'NUMERICAL CALCULATION OF ELLIPTIC INTEGRALS   ELIP0039
C                                         AND ELLIPTIC FUNCTIONS', HANDBOOK SERIES SPECIAL FUNCTIONS,   ELIP0040
C                                         NUMERISCHE MATHEMATIK VOL. 7, 1965, PP. 78-90.   ELIP0041
C                                         .....          ELIP0042
C                                         SUBROUTINE CELI2(RES,AK,A,B,IER)   ELIP0043
C                                         IER=0          ELIP0044
C                                         TEST RANGE      ELIP0045
C                                         CK=AK*AK        ELIP0046
C                                         IF(CK<1.) 20,20,10   ELIP0047
C                                         10  IER=1        ELIP0048
C                                         RETURN         ELIP0049
C                                         .....          ELIP0050
C                                         .....          ELIP0051
C                                         .....          ELIP0052
C                                         .....          ELIP0053
C                                         .....          ELIP0054
C                                         .....          ELIP0055
C                                         .....          ELIP0056
C                                         .....          ELIP0057
C                                         .....          ELIP0058
C                                         .....          ELIP0059
C                                         .....          ELIP0060
C                                         .....          ELIP0061

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C           COMPUTE COMPLEMENTARY MODULUS          ELIPO062
C
C           20 GEO=SQRT(1.0-CK)                      ELIPO063
C               IF(GEO) 70,30,70                      ELIPO064
C
C           SET RESULT VALUE = OVERFLOW             ELIPO065
C
C           30 IF(B) 40,60,50                         ELIPO066
C           40 RES=-1.E38                           ELIPO067
C               RETURN                               ELIPO068
C           50 RES=1.E38                           ELIPO069
C               RETURN                               ELIPO070
C           60 RES=A                            ELIPO071
C               RETURN                               ELIPO072
C
C           COMPUTE INTEGRAL                      ELIPO073
C
C           70 ARI=1.                                ELIPO074
C               AA=A                                ELIPO075
C               AN=A+B                            ELIPO076
C               W=B                                ELIPO077
C           80 W=W+AA*GEO                          ELIPO078
C               W=W+W                            ELIPO079
C               AA=AN                            ELIPO080
C               AARI=ARI                          ELIPO081
C               ARI=GEO+ARI                        ELIPO082
C               AN=W/ARI+AN                        ELIPO083
C
C           TEST OF ACCURACY                     ELIPO084
C
C           IF(AARI-GEO-1.E-4*AARI) 100,100,90    ELIPO085
C           90 GEO=SQRT(GEO*AARI)                  ELIPO086
C               GEO=GEO+GEO                      ELIPO087
C               GO TO 80                           ELIPO088
C
C           100 RES=.78539816*AN/ARI                ELIPO089
C               RETURN                             ELIPO090
C               END                                ELIPO091

```

```

$IBFTC TRP2      M94,XR7,DECK
  REAL FUNCTION TRP2(T,X,Y,M)
  DIMENSION T( 1003),Z(4),D(6)
  L1=0
  X1=X
  Y1=Y
  I=T(1)/1000.+1.
  J=AMOD(T(1),1000.)+1.
  L=J*M
  I1=J*3+1
  I2=I*J
  M1=M
  DO 10 K=I1,I2,L
  IF(X1-T(K)) 20,20,10
10 CONTINUE
  K=I2+1-J
20 DO 30 L=4,J,M1
  IF (Y1-T(L)) 40,40,30
30 CONTINUE
  L=J
40 L1=L1+1
  DO 50 MN=1,3
  N=L+MN-3
  N1=K+(J*(L1-3))+N-1
  D(MN)=T(N)
50 D(MN+3)=T(N1)
60 Z(L1)=D(4)+(Y1-D(1))*((D(5)-D(4))/(D(2)-D(1))+(
  1Y1-D(2))/(D(3)-D(1))*((D(6)-D(5))/(D(3)-D(2))-
  2-(D(5)-D(4))/(D(2)-D(1))))
  IF (L1-3)40,70,90
70 DO 80 MN=1,3
  D(MN+3)=Z(MN)
  N1=K+(J*(MN-3))
80 D(MN)=T(N1)
  L1=4
  Y1=X
  GO TO 60
90 TRP2=Z(4)
  RETURN
  END

```

TRP20000
TRP20001
TRP20002
TRP20003
TRP20004
TRP20005
TRP20006
TRP20007
TRP20008
TRP20009
TRP20010
TRP20011
TRP20012
TRP20013
TRP20014
TRP20015
TRP20016
TRP20017
TRP20018
TRP20019
TRP20020
TRP20021
TRP20022
TRP20023
TRP20024
TRP20025
TRP20026
TRP20027
TRP20028
TRP20029
TRP20030
TRP20031
TRP20032
TRP20033
TRP20034
TRP20035
TRP20036
TRP20037
TRP20038
TRP20039

```
$18FTC TIFANY M94,XR7,DECK  
BLOCK DATA  
COMMON /MKCURV/ MK(1000)  
REAL MK  
DATA(MK(I),I=1,84)/  
1 11006.,0.05,0.10,0.20,0.30,0.40,0.50,  
2 0.0,1.00,1.00,1.00,1.00,1.00,1.00,  
3 0.1,1.01,1.01,1.01,1.01,1.01,1.00,  
4 0.2,1.03,1.03,1.02,1.02,1.01,1.00,  
5 0.3,1.06,1.06,1.04,1.03,1.02,1.00,  
6 0.4,1.12,1.12,1.08,1.05,1.02,1.00,  
7 0.5,1.22,1.18,1.14,1.08,1.03,1.00,  
8 0.6,1.34,1.30,1.22,1.13,1.06,1.01,  
9 0.7,1.48,1.42,1.31,1.20,1.08,1.02,  
A 0.8,1.64,1.57,1.41,1.26,1.13,1.04,  
B 0.9,1.77,1.68,1.50,1.32,1.18,1.08,  
C 1.0,1.84,1.75,1.59,1.38,1.22,1.10/  
END
```

TIFA0000
TIFA0001
TIFA0002
TIFA0003
TIFA0004
TIFA0005
TIFA0006
TIFA0007
TIFA0008
TIFA0009
TIFA0010
TIFA0011
TIFA0012
TIFA0013
TIFA0014
TIFA0015
TIFA0016
TIFA0017

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AFFDL-TR-70-107

APPENDIX II
ILLUSTRATIVE PROBLEM

Let's consider a typical mission profile for a tactical aircraft. This mission will consist of: a low level penetration run, a pullup over the target, a military power climb, a roll and pullover, a dive followed by a 5 "g" pullup, a low level dash followed by a 4 "g" pullup into a military power climb and return cruise to a normal landing. The flight description is taken from reference 9 and is given in Table II and loads description in Table III. Assume that during the low level penetration, the aircraft sustains damage which may be modeled as a through crack of length 1.74 inches. The input cards for this problem are given in Table IV and the output is in Table V. If the damage is modeled as a through crack of length 2.103, the input changes are shown in Table VI and the output is in Table VII. Comparisons with analytical results from reference 9 show that both analyses predict the same number of cycles to failure for both cases.

TABLE II
MISSION PROFILE DESCRIPTION

Condition	Description	Airspeed	n_z	Number Gust Cycles	
				$\Delta n_z = 0.26$	$\Delta n_z = 0.42$
1	Low Level Dash	450 kt	1	8	-
2	180° Turn	450 kt	2	8	-
3	Low Level Dash	450 kt	1	8	-
4	180° Turn	450 kt	2	8	-
5	Low Level Dash	450 kt	1	8	-
6	180° Turn	450 kt	2	8	-
7	Low Level Dash	450 kt	1	8	-
8	180° Turn	450 kt	2	8	-
9	Low Level Dash	450 kt	1	8	-
10	180° Turn	450 kt	2	8	-
11	Low Level Dash	450 kt	2	8	-
12	180° Turn	450 kt	2	8	-
13	Low Level Dash	450 kt	2	8	-
14	Pullup	450 kt	4	-	-
15	Military Power Climb	0.87 M	0	-	-
16	Roll and Pullover	0.87 M	3	-	-
17	Dive	0.87 M	0	-	-
18	Pullup	0.87 M	5	-	-
41	Military Power Climb	0.87 M	0	64	8
42	Cruise	0.87 M	1	16	3
43	Descend	0.87 M	0	8	1
44	Low Level Flight	175 kt	1	12	2
45	180° Turn	175 kt	2	12	2
46	Low Level Flight	175 kt	1	12	2
47	180° Turn	175 kt	2	12	2
48	Final Descent	145 kt	0	-	-

TABLE III
LOADS FOR MISSION PROFILE

Cond	$\Delta\sigma$ (psi)	R	N (cycles)	Cond	$\Delta\sigma$	R	N (cycles)
1	4850	0	1	12	6470	0.256	1
1	2000	0.588	7	12	2000	0.770	7
1	3240	0.408	1	12	3240	0.652	1
2	6470	0.256	1	13	2000	0.588	8
2	2000	0.770	7	13	3240	0.408	1
2	3240	0.652	1	14	13170	0.145	1
3	2000	0.588	8	15-16	11450	0.009	1
3	3240	0.408	1	17-18	19150	0.005	1
4	6470	0.256	1	41	2000	0.194	64
4	2000	0.770	7	41	3240	0.031	8
4	3240	0.652	1	42	5370	0.019	3
5	2000	0.588	8	42	2000	0.588	16
5	3240	0.408	1	43	2000	0.194	8
6	6470	0.256	1	43	3240	0.031	1
6	2000	0.770	7	44	5370	0.019	1
6	3240	0.652	1	44	2000	0.588	12
7	2000	0.588	8	44	3240	0.408	1
7	3240	0.408	1	45	7090	0.240	1
8	6470	0.256	1	45	2000	0.770	12
8	2000	0.770	7	45	3240	0.652	1
8	3240	0.652	1	46	2000	0.588	12
9	2000	0.588	8	46	3240	0.408	2
9	3240	0.408	1	47	7090	0.240	1
10	6470	0.256	1	47	2000	0.770	12
10	2000	0.770	7	47	3240	0.652	1
10	3240	0.652	1				
11	2000	0.588	8				
11	3240	0.408	1				

TABLE IV
DATA DECK FOR PROBLEM 1

OTFDTRJUL65100

TABLE IV (CONTD)

	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
OTEDTRUL65100	3240.
7	0.408
8	0.256
9	0.770
10	0.652
11	0.588
12	0.408
13	0.256
14	0.770
15	0.652
16	0.588
17	0.408
18	0.256
19	0.770
20	0.652
21	0.588
22	0.408
23	0.256
24	0.770
25	0.652
26	0.588
27	0.408
28	0.256
29	0.770
30	0.652
31	0.588
32	0.408
33	0.256
34	0.770
35	0.652
36	0.588
37	0.408
38	0.256
39	0.770
40	0.652

TABLE IV (CONTD)

CTFDTRIUL 65100

		1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40.
44	5370.	0.019
44	2000.	0.588
44	3240.	0.408
45	7090.	0.240
45	2000.	0.770
45	3240.	0.652
46	2000.	0.588
46	3240.	0.408
47	7090.	0.240
47	2000.	0.770
47	3240.	0.652
END		

TABLE V

TYPICAL FIGHTER-BOMBER MISSION

MATERIAL CONSTANTS	7075-T6 ALUMINUM		
C = 0.51300000E-12	SMALLN = 3.00	KSUBC = 0.38999999E .05	YIELD STRESS = -0.
INITIAL HALF CRACK LENGTH	= C.17399999E .01		
CORRECTION FACTORS USED FOR DELTA K			
DELTA K = (DELTA T)*SQRT(PI*A)*BETA(1)*BETA(2)*...*BETA(I)			
BETA(2)-FINITE WIDTH CORRECTION FACTOR			
BETA(2) = SQRT(2/(PI*A/B))*TAN(PI*(A/B)/2)			
WHERE...B = 0.80000000E .01			
INITIAL CYCLE NUMBER	= 0.		
REPEAT INPUT SPECTRUM	4 TIMES		

TABLE V (CONT'D)

LOAD BLOCK	NUMBER OF CYCLES PER LOAD BLOCK	NUMBER OF CYCLE AT END OF BLOCK	DELTA SIGMA	INTEGRATION INTERVAL (CYCLES)	
				R	R'
1	1	1.000	4850.00	1.000	1.000
1	2	7.000	2000.00	7.000	7.000
1	3	1.000	8.000	0.406	1.000
1	4	1.000	9.000	0.406	1.000
2	2	7.000	10.000	0.256	1.000
2	5	7.000	17.000	0.256	1.000
2	6	1.000	18.000	0.770	1.000
2	7	8.000	26.000	0.652	1.000
3	3	1.000	26.000	0.588	1.000
3	8	1.000	27.000	0.406	1.000
3	9	1.000	28.000	0.256	1.000
4	10	7.000	35.000	0.770	1.000
4	11	1.000	36.000	0.652	1.000
5	12	8.000	44.000	0.588	1.000
5	13	1.000	45.000	0.406	1.000
5	14	1.000	46.000	0.256	1.000
6	15	7.000	53.000	0.770	1.000
6	16	1.000	54.000	0.652	1.000
6	17	8.000	62.000	0.588	1.000
7	18	1.000	63.000	0.406	1.000
7	19	1.000	64.000	0.256	1.000
8	20	7.000	71.000	0.770	1.000
8	21	1.000	72.000	0.652	1.000
9	22	8.000	80.000	0.588	1.000
9	23	1.000	81.000	0.406	1.000
10	24	1.000	82.000	0.256	1.000
10	25	7.000	89.000	0.770	1.000
10	26	1.000	90.000	0.652	1.000
11	27	8.000	98.000	0.588	1.000
11	28	1.000	99.000	0.406	1.000
12	29	1.000	100.000	0.256	1.000
12	30	7.000	107.000	0.770	1.000
12	31	1.000	108.000	0.652	1.000
12	32	8.000	116.000	0.588	1.000
13	33	1.000	117.000	0.406	1.000
13	34	1.000	118.000	0.256	1.000
14	35	1.000	119.000	0.009	1.000
15-16	36	1.000	120.000	0.31	1.000
17-18	37	1.000	120.000	0.194	1.000
41	38	8.000	192.000	0.631	1.000
41	39	3.000	195.000	0.019	1.000
42	40	1.000	200.000	0.588	1.000
42	41	8.000	211.000	0.194	1.000
43	42	1.000	219.000	0.31	1.000
43	43	1.000	220.000	0.194	1.000
44	43	1.000	221.000	0.019	1.000
44	44	12.000	223.000	0.588	1.000
44	45	1.000	233.000	0.406	1.000
45	46	1.000	235.000	0.240	1.000
45	47	1.000	247.000	0.770	1.000
45	48	12.000	261.000	0.652	1.000
46	49	2.000	324.000	0.588	1.000
46	50	1.000	326.000	0.406	1.000
47	51	1.000	323.000	0.240	1.000
47	52	1.000	325.000	0.770	1.000
47	53	1.000	326.000	0.652	1.000

TABLE V (CONT'D)

LOAD BLOCK	NUMBER OF CYCLES PER LOAD BLOCK	NUMBER OF CYCLE AT END OF BLOCK	DELTA SIGMA	R	INTEGRATION INTERVAL (CYCLES)
1	1.000	1.000	4850.00	0.586	1.000
1	2	7.000	8.000	0.408	7.000
1	3	1.000	9.000	0.256	1.000
2	4	1.000	10.000	0.256	1.000
2	5	7.000	17.000	0.770	7.000
2	6	1.000	18.000	0.652	1.000
2	7	8.000	26.000	0.588	8.000
3	8	1.000	27.000	0.408	1.000
3	9	1.000	28.000	0.256	1.000
4	10	7.000	35.000	0.770	7.000
4	11	1.000	36.000	0.652	1.000
5	12	8.000	44.000	0.588	8.000
5	13	1.000	45.000	0.408	1.000
5	14	1.000	46.000	0.256	1.000
6	15	7.000	53.000	0.770	7.000
6	16	1.000	54.000	0.652	1.000
6	17	8.000	62.000	0.588	8.000
7	18	1.000	63.000	0.408	1.000
7	19	1.000	64.000	0.256	1.000
8	20	7.000	71.000	0.770	7.000
8	21	1.000	72.000	0.652	1.000
9	22	8.000	80.000	0.588	8.000
9	23	1.000	81.000	0.408	1.000
10	24	1.000	82.000	0.256	1.000
10	25	7.000	69.000	0.770	7.000
10	26	1.000	70.000	0.652	1.000
11	27	8.000	98.000	0.588	8.000
11	28	1.000	99.000	0.408	1.000
12	29	1.000	100.000	0.256	1.000
12	30	7.000	107.000	0.770	7.000
12	31	1.000	108.000	0.652	1.000
12	32	8.000	116.000	0.588	8.000
13	33	1.000	117.000	0.408	1.000
13	34	1.000	118.000	0.256	1.000
14	35	1.000	119.000	0.009	1.000
14	36	1.000	120.000	0.5	1.000
14	37	1.000	121.000	0.194	1.000
15-16	38	8.000	192.000	0.031	8.000
15-16	39	3.000	195.000	0.019	3.000
41	40	1.000	197.000	0.588	1.000
41	41	1.000	200.000	0.194	1.000
42	42	1.000	201.000	0.770	1.000
43	43	1.000	204.000	0.652	1.000
43	44	1.000	205.000	0.588	1.000
44	44	12.000	221.000	0.019	12.000
44	45	1.000	223.000	0.588	1.000
45	45	1.000	224.000	0.408	1.000
45	46	1.000	235.000	0.240	1.000
45	47	12.000	247.000	0.770	12.000
45	48	1.000	248.000	0.652	1.000
46	49	12.000	266.000	0.588	12.000
46	50	2.000	262.000	0.408	2.000
47	51	1.000	263.000	0.240	1.000
47	52	12.000	275.000	0.770	12.000
47	53	1.000	276.000	0.652	1.000

TABLE VI
DATA DECK FOR PROBLEM 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
OTFDTRJUL65100																																								
TYPICAL FIGHTER-BOMBER MISSION																																								
FORMAN																																								
5.138-13																																								
2.103																																								
BETA2																																								
BETAO																																								
0.																																								
RANGE																																								
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TABLE VI (CONTD)

		1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
	OTFDTRIJUL65100	
7	3240.	0. 108
8	6470.	0. 256
8	2000.	0. 770
8	3240.	0. 652
9	2000.	0. 588
9	3240.	0. 408
10	6470.	0. 256
10	2000.	0. 770
10	3240.	0. 652
11	2000.	0. 588
11	3240.	0. 408
12	6470.	0. 256
12	2000.	0. 770
12	3240.	0. 652
13	2000.	0. 588
13	3240.	0. 408
14	13170.	0. 145
15-16	11450.	0. 009
17-18	19150.	0. 005
41	2000.	0. 194
41	3240.	0. 031
42	5370.	0. 019
42	2000.	0. 588
43	2000.	0. 194
43	3240.	0. 031

TABLE VI (CONTD)

TABLE VII

TYPICAL FIGHTER-BOMBER MISSION

```

MATERIAL CONSTANTS      7075-T6 ALUMINUM
C = C.5130C33E-12      KSMALLN = 3.00      KSUBC = 3.38499999E 05      YIELD STRESS = -0.
INITIAL HALF CRACK LENGTH = 0.2102999E 01
CORRECTION FACTORS USED FOR DELTA K
DELTA K =(DELTA T)*SQR(PI*A)*BETA(1)*BETA(2)*...*BETA(11)
BETA(12)=FINITE WIDTH CORRECTION FACTOR
BETA(12) = SQR(2/(PI*A/B))*JAN(PI*(A/B)/2)
WHERE....B = 0.80000000E 01
INITIAL CYCLE NUMBER = 0.
REPEAT INPUT SPECTRUM 4 TIMES

```

TABLE VII (CONT'D)

LOAD BLOCK	NUMBER OF CYCLES PER LOAD BLOCK	NUMBER OF CYCLE AT END OF BLOCK	DELTA SIGMA	K	INTEGRATION INTERVAL (CYCLES)	
					1.000	1.000
1	1	1.000	4850.00	0.588	0.588	0.588
1	2	7.000	8.000	2000.00	7.000	7.000
1	3	1.000	9.000	3240.00	1.000	1.000
1	4	1.000	10.000	6470.00	0.256	0.256
2	2	7.000	17.000	2000.00	7.000	7.000
2	5	1.000	18.000	3240.00	1.000	1.000
2	6	8.000	26.000	2000.00	0.588	0.588
3	3	8.000	27.000	3240.00	1.000	1.000
3	8	1.000	28.000	6470.00	0.256	0.256
3	9	1.000	28.000	2000.00	0.770	0.770
4	4	1.000	35.000	3240.00	0.692	0.692
4	13	7.000	36.000	2000.00	0.588	0.588
4	11	1.000	44.000	3240.00	1.000	1.000
4	12	8.000	45.000	6470.00	0.256	0.256
5	13	1.000	45.000	3240.00	1.000	1.000
5	14	1.000	46.000	6470.00	0.256	0.256
6	6	1.000	53.000	2000.00	0.770	0.770
6	15	7.000	54.000	3240.00	0.692	0.692
6	16	1.000	62.000	2000.00	0.588	0.588
6	17	8.000	63.000	3240.00	1.000	1.000
7	7	1.000	63.000	6470.00	0.256	0.256
7	18	1.000	64.000	3240.00	1.000	1.000
7	19	1.000	64.000	6470.00	0.256	0.256
8	8	7.000	71.000	2000.00	0.770	0.770
8	21	1.000	72.000	3240.00	0.692	0.692
8	22	8.000	80.000	2000.00	0.588	0.588
9	9	1.000	81.000	3240.00	1.000	1.000
9	23	1.000	82.000	6470.00	0.256	0.256
10	10	7.000	89.000	2000.00	0.770	0.770
10	24	1.000	90.000	3240.00	0.692	0.692
10	25	1.000	90.000	6470.00	0.256	0.256
11	10	26	98.000	2000.00	0.588	0.588
11	27	8.000	98.000	3240.00	1.000	1.000
11	28	1.000	99.000	6470.00	0.256	0.256
11	29	1.000	100.000	3240.00	1.000	1.000
12	12	7.000	107.000	2000.00	0.770	0.770
12	30	1.000	108.000	3240.00	0.692	0.692
12	31	1.000	108.000	6470.00	0.256	0.256
12	32	8.000	116.000	2000.00	0.588	0.588
13	13	1.000	117.000	3240.00	1.000	1.000
13	33	1.000	118.000	6470.00	0.256	0.256
14	34	1.000	119.000	3240.00	1.000	1.000
14	35	1.000	120.000	6470.00	0.256	0.256
15-16	36	1.000	121.000	3240.00	1.000	1.000
17-18	37	1.000	121.000	6470.00	0.256	0.256
41	41	38	8.000	192.000	0.031	0.031
41	42	39	12.000	3240.00	0.588	0.588
41	43	40	16.000	195.000	0.019	0.019
41	44	44	1.000	211.000	0.588	0.588
44	45	45	1.000	234.000	0.145	0.145
44	46	46	1.000	235.000	0.009	0.009
45	47	47	12.000	219.000	0.194	0.194
45	48	48	1.000	220.000	0.025	0.025
45	49	49	12.000	184.000	0.194	0.194
46	50	50	2.000	200.00	0.031	0.031
46	51	51	1.000	262.000	0.588	0.588
47	52	52	12.000	263.000	0.240	0.240
47	53	53	1.000	275.000	0.770	0.770
				276.300	0.652	0.652

TABLE VII (CONT'D)

CRACK LENGTH AT BEGINNING OF FLIGHT 1 IS 2.10300
 CRACK PROPAGATION ANALYSIS USING FORMAN'S EQUATION
 $DA/DN = C * \text{DELTA K} * \pi N / ((1-R) * K_{SUBC} - \Delta K)$

CYCLE	A	DA/DN	DELTA K	K MAX	K SUBK
1.000	2.10304	0.415232291E-04	12840.99	1.000	
8.900	2.10309	0.70108467E-05	5295.32	1.000	
9.000	2.10311	0.2320025E-05	8578.48	1.000	
10.000	2.10313	0.2102959E-03	17131.47	1.000	
10.000	2.10311	0.2102959E-03	17131.47	1.000	
17.000	2.10317	0.2038335E-04	5295.87	1.000	
17.000	2.10317	0.2038335E-04	5295.87	1.000	
18.000	2.10318	0.64889476E-04	8579.45	1.000	
26.000	2.10354	0.7041612E-05	5296.04	1.000	
27.000	2.10362	0.22308522E-05	8579.64	1.000	
28.000	2.10384	0.21715993E-03	17133.78	1.000	
35.000	2.10398	0.2050789E-05	5296.58	1.000	
36.000	2.10405	0.66302879E-04	8580.61	1.000	
44.000	2.10410	0.7075209E-05	5296.76	1.000	
45.000	2.10413	0.2241695E-05	8580.79	1.000	
46.000	2.10434	0.21729036E-03	17136.10	1.000	
53.000	2.10449	0.2263253E-05	5297.30	1.000	
54.000	2.10455	0.64972316E-05	8581.77	1.000	
62.000	2.10461	0.70308626E-05	5297.47	1.000	
63.000	2.10463	0.2252545E-05	8581.95	1.000	
64.000	2.10485	0.21742992E-03	17138.42	1.000	
71.000	2.10499	0.2075728E-05	5298.02	1.000	
72.000	2.10506	0.65313792E-04	8582.93	1.000	
85.000	2.10512	0.70342062E-05	5298.19	1.000	
81.000	2.10514	0.22363402E-04	8583.12	1.000	
82.000	2.10536	0.2155163E-03	17140.73	1.000	
89.000	2.10550	0.20788224E-04	5298.73	1.000	
90.000	2.10557	0.6555523E-04	6564.10	1.000	
98.000	2.10562	0.70875566E-05	5298.90	1.000	
99.000	2.10565	0.22374275E-04	8584.28	1.000	
100.000	2.10586	0.2116825E-03	17143.05	1.000	
107.000	2.10661	0.20000725E-04	5299.45	1.000	
108.000	2.10667	0.6596924E-04	8585.26	1.000	
116.000	2.10613	0.7009073E-05	5299.62	1.000	
117.000	2.10615	0.22385161E-04	8585.44	1.000	

((1-R)K_{SUBC}-DELTA K) WENT NEGATIVE AT 117.000 CYCLESBEGIN SEARCH FOR MORE ACCURATE VALUES
STARTING VALUES

117.000 2.10615 1.000

*****VALUES AT ONSET OF INSTABILITY*****

117.000 2.10615 1.000

8585.44

14502.43

1.000

1.000

1.000

0.

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Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and Indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Air Force Flight Dynamics Laboratory, Structures Division Solid Mechanics Branch, Wright-Patterson Air Force Base, Ohio 45433		2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED
2b. GROUP		
3. REPORT TITLE CRACKS - A FORTRAN IV DIGITAL COMPUTER PROGRAM FOR CRACK PROPAGATION ANALYSIS		
4. DESCRIPTIVE NOTES (Type of report and Inclusive dates) FINAL Technical Report (July 69 - Mar 70)		
5. AUTHOR(S) (First name, middle initial, last name) Robert M. Engle, Jr.		
6. REPORT DATE October 1970	7a. TOTAL NO. OF PAGES 60	7b. NO. OF REFS 9
8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S) AFFDL-TR-70-107	
b. PROJECT NO. 1467	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
c. Task No. 146704		
d.		
10. DISTRIBUTION STATEMENT This document has been approved for public release and sale; its distribution is unlimited.		
11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Air Force Flight Dynamics Laboratory, Structures Division, Wright-Patterson Air Force Base, Ohio	
13. ABSTRACT This report presents a detailed description of a computer program for analyzing crack propagation in cyclic loaded structures. The program has the option of using relationships derived by Forman or by Paris for crack growth. Provisions are made for both surface flaws and "through cracks" as well as the transition from the former to the latter. The program utilizes a block loading concept wherein the load is applied for a given number of cycles rather than applied from one cycle number to another cycle number. Additional features of the program are: variable print interval, variable integration interval, and optional formats for loads input. Detailed input instructions and an illustrative problem are presented.		

DD FORM 1 NOV 68 1473

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14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
1. Crack Propagation 2. Variable Amplitude Loading 3. Digital Computer Methods						

UNCLASSIFIED

Security Classification